HIGHER ENGINEERING EDUCATION: WHICH TYPE IS REALLY NEEDED? ENGINEERING SCIENCE OR ENGINEERING TECHNOLOGY

Muhammad Taher Abuelma'atti[1]

1: Dept. of Electrical Engineering, KFUPM

Box 203 Dhahran 31261 Saudi Arabia
E-mail: mtaher@kfupm.edu.sa

ABSTRACT

This paper is an attempt to provide an answer to the question of which type of higher engineering education is really needed in Saudi Arabia? The paper discusses the skills required by the local industry at the engineers level. Engineering curricula and the training required to meet these requirements are discussed. Possible areas of deficiencies in the current programs are outlined. It then recommends that, under the present conditions, engineering technology education is more appropriate. Recommendations for possible improvements in the current engineering curricula are presented.

Keywords: *Engineering education and training, Curriculum design, University-industry relationship*

الملخص

هذه الورقة تمثل محاولة للإجابة علي السؤال الملح عن طبيعة برامج التعليم العالي الهندسي الملائمة للمرحلة الحالية من التطور الصناعي والتقني في المملكة العربية السعودية . تناقش الورقة المهارات الهندسية المطلوبة للصناعات المحلية ومدى وفاء الجامعات السعودية بالتزاماتها لتوفير هذه المهارات وتقترح الورقة التركيز على التعليم العالي الهندسي التقني حيث أنة ألأكثر ملاءمة للتطور التقني و الصناعي الحالي في المملكة العربية السعودية .

1. INTRODUCTION

It is well known that the key to the economic growth and development of any nation is based on trained human resources. The difference between two companies producing and selling the same product in the same market seldom lies in the materials or equipment used. It usually lies in the kind of personnel they have, their knowledge, skills and attitudes, and how they work together as a team.

People are, therefore, the greatest potential assets to any country or organization. They make the difference in the achievement level of different organizations. Therefore, for any nation to grow and develop economically it must consider seriously the production of educated and trained human resources at the various levels of the country's socioeconomic system. Of all the resources required for economic development, high-level manpower requires the longest 'lead-time' for preparation. Modern dams, power stations, textile factories or steel mills can be constructed within a few years. But it takes between 10 and 15 years to develop managers Development of administrators and engineers takes few years- but it requires decades to develop high-level educators and professors. The development of human resources is a major task of universities and other higher education institutions.

Fortunately, at present, there is growing demand for higher education, and the proportion of young people entering post-secondary education is growing rapidly. Our universities are, therefore, under tremendous pressure to cope with the masses now aiming for enrollment in general, and specially in engineering. This results in tremendous efforts and measures to be taken to balance student numbers against institutional capacity while maintaining, and preferably improving, both relevance and capacity. Moreover, it is becoming impossible for the state to support the growing number of students from the public budget alone. The universities are urged and encouraged to generate other sources of income. Furthermore, it is obvious that the present universities cannot-and should not- meet all the different types of post-secondary education that are now in demand, both from young people and from different employers, especially the private sector. Universities cannot do this and still remain universities. It will be beyond the means of present universities to accommodate all types of post-secondary education. Sensible and meaningful non-university educational opportunities must be established. In fact there is a significant difference between a typical traditional research-oriented university and the non-university higher education institutions.

1.1. Types Of Higher Education

Higher education, in general, shall be equally accessible to all on the basis of merit. But this does not mean that everybody has a right to enroll in a traditional research-oriented university. Higher education must be diversified, making it possible for the students to find a type of education that is in accordance with their talents and needs as well as the needs of the society. Higher engineering education is, of course, no exception. However, diversification of higher education should be among institutions and not within institutions. It is preferable to have different types of institutions for post-secondary education, institutions with different and distinctive missions, different styles of teaching, training for different careers, and with a different relationship to research. It is important to emphasize here that an institution devoted mainly to teaching is not a failed research university, but an institution with a special charter and mission, with great possibilities for innovation and adaptation to the wishes of both the students and labor market.

On the other hand, the interface between industry, the education and training system is becoming increasingly complex. Both sides of the industry/education divide are struggling to face up to the seemingly inexorable demand for better skilled people whilst facing commercial and political pressures to reduce costs and increase throughput. Many of the arguments about industry's requirements of the education system and the educational establishment's ability to meet these requirements are well rehearsed. However, much of the argument generates more heat than light and both sides of the divide spend much time either defending the status quo or establishing unachievable criteria for their people and skill requirements.

1.2. The Critical Question

At this point, it is important to note that most of the companies in the developing countries are not involved in research and development, especially in the area of engineering. There are mainly service providers, acquiring hi-tech products from third party companies rather than manufacturing them. Therefore, at present, the skills required by the Saudi industrial organizations can be classified as maintenance planning and implementation, engineering and economic evaluation of specifications and monitoring installation and maintenance contracts. This raises the question: ***are our universities providing the right training for engineers to serve the local industries?***

1.3. Object Of The Study

The major intention of this paper is, therefore, to answer this question and to suggest possible remedial actions. A review of the major differences between university and non-university engineering higher education will be presented. The rules and attitudes of these two different institutions will be discussed and some suggestions for possible remedial actions to improve the present situation will be introduced.

2. ISSUES FOR HIGHER EDUCATION

The requirements to recruit better qualified individuals into the industry and to upgrade the skills of the existing employees have important implications for higher and further education in Saudi Arabia. There have to be questions about the type and quality of degrees being offered when the chorus of complaint from industrial recruiters is heard. Many people question whether the rather elitist approach to engineering education adopted by faculties in engineering colleges does anymore than underpin the training and qualifications of the relatively small number of professional engineers required by industry. The real demand is for higher technicians who, these days, increasingly come through the university route and require broader based and more application-oriented degrees than those undertaken by young people pursuing the more academic courses [Mackenzie, 1999].

Employers feel that there is a lack of rigor in many university courses and applaud the recommendations to tighten the degree standards and to require programs specifications so as to ensure that degree courses are tailored to the requirements of industry as well as to those of undergraduates. In this process, the requirements of small employers should not be overlooked. Increasingly, undergraduates go out of higher education into the small-company employment sector. Many of these small-company employers have little experience of recruiting and training graduates. So relationships between higher education and small companies need to be reviewed to better facilitate this aspect of the recruitment process.

Just as important, higher education institutions have a vital role to play in the development and delivery of courses to upskill the existing workforce. In the developed countries, there are a number of good examples of collaborative programs between companies and particular higher educational institutions which are directed at meeting the requirement for lifelong learning. It is hard, however, to see such collaborative programs in developing countries. This aspect of higher education needs radical expansion whilst maintaining the quality and standards of the learning delivered.

In developing countries, while the needs of the industry are understood, it is far from clear that the implications for its people requirements have been properly fed through to education and training providers at all levels in the system. Nevertheless, there is a growing constructive dialogue which should lead to the better tailoring of the output from the education system to industry's needs [Zaky and El-Faham, 1998] and [Jazi, 2001].

3. UNIVERSITY ROLE

The key to developing countries economic growth and development is not commodities, but trained human resources. The most important resource in developing, and developed, countries is people. For universities to discharge their responsibilities to the nation they must generate graduates who are well-suited to fulfil the essential needs of industry. The prime responsibility of universities is to educate successive generations of students in accordance with developments in each discipline. In order to achieve this goal, and to assist in the advancement of knowledge, a university must attract the highest caliber of students. This is also of importance to industry because most of the graduates will enter companies and help to ensure the viability of the country's industrial capability in the future decades. Universities must offer courses which are useful for both the students and the industry. Able students often express a desire to be involved in broadly-based course work, such that it will prepare them more effectively for future industry careers. For a university to meet its target it is essential to remember that:

a. The training of students is the basic mission of the university while teaching and research are the means not the ends of it. The first function of the university is to assist the individual in the achievement of his full intellectual powers and capacities, and its second function is to assist the community and the state in developing the necessary knowledge for training technologists, specialists and professionals increasingly required in modern society.

Institutions will have to show greater flexibility in order to anticipate, and adapt to, the needs of society, especially in developing countries, where it is urgent to establish new types of university models that are better suited to the needs of these countries and mobilize regional synergies and cooperation.

b. To wish at all cost to imitate the large universities of the developed countries would be fatal, in my opinion. In these countries, universities must be established on new models linked with, and serving the needs of, the local industries. This may avoid massive brain drain and enable the rapid transfer of knowledge and technology. It is important, to remember that higher education in universities and other institutions is aimed at:

1. the acquisition, development and timely inculcation of the proper value-orientation for the survival of the individual and society;
2. the development of the intellectual capacities of individuals to understand and appreciate their environment;
3. the acquisition of both physical and intellectual skills which will enable individuals to develop into useful members of the community;
4. to train the whole man for nation building; and
5. to develop completely human resources for meeting manpower needs.

Unfortunately, in developing countries little or no effort has been made to bridge the ever-widening university-industry gap. There are several reasons for this. Of particular importance here are the following:

- In univerisities, curricula are modelled on those of the universities in developed countries where most of the faculty have completed their graduate studies. For reasons of prestige and recognition, the needs of local industries are usually ignored. Unfortunately, in many occasions the requirements of the local industries are considered well below university standards.

- Industry is not carrying out need analysis, especially the human resources it needs, in specific areas, to achieve its goals. Industry is not providing support for student projects, long term research, continuing education programs in specific areas and is not encouraging consulting.

Of prime importance are the education and training of graduates in large numbers who are competent in all fields, particularly in science and technology.

Top

c. Graduates need the skill of learning how to learn, self learning, possibly from computer-aided instruction through the Internet, interactive long distance learning and other means.
Today, success of an engineer depends on a number of factors. With increasingly demanding jobs it is critically important to be able to demonstrate continuing professional competence. Personal aspirations and changes in technology and company structures require continuing professional development (CPD) to be high on everyone's agenda. CPD can be defined as: The systematic maintenance, improvement and broadening of knowledge, understanding and skill, and the development of personal quality necessary for the execution of professional and technical duties throughout the individual's working life [Upton, 2000]. Engineers have always had to update their knowledge and skills. Today, with the increasing use of the Internet and the availability of increasing number of interactive long distance learning programs, it is not difficult for engineers to acquire the necessary skills to meet the challenge of lifelong learning [Midwinter, 1999].

Graduates have to exercise technical judgements, understand the principles underlying their work and the purpose of what they are doing and often supervise other staff. These requirements envision major curricula structure reform to bridge the gap between universities and industry. However, an essential prerequisite for any curricula structure reform, is a detailed study of the skills required for the graduate engineers to serve the local industry.

4. SKILL REQUIREMENTS FOR ENGINEERS

According to a recently published report [Al-Qahtani, 2000], the skill requirements for engineers in a developing country are:

1. Prepare technical specifications for maintenance contracts, for the procurement of new systems and equipment under expansion schemes. Also, prepare technical specifications for those equipment and systems that have outlived and are required to be replaced or upgraded according to a replacement scheme.
2. Monitor installation and maintenance contracts.
3. Carryout technical tests on completed projects for compliance with specifications and the use of material and equipment.
4. Modify and alter the existing facilities to improve performance or to keep them operating at times when spares are not available.
5. Review designs and specifications for new equipment and systems proposed and to coordinate and provide guidance to resolve conflicts between the designs and the requirements.
6. Plan, schedule and coordinate shutdown and overhaul jobs and to take independent decisions in this connection.

7. Provide close supervision to technicians in case the situation demands component level repairs of sophisticated systems.
8. Disseminate information to the head of engineering department on all matters affecting policy, established procedures, training, staffing level, safety, continuity of engineering services and technical developments.
9. Assist the head of department in preparing the engineering budget consisting of activity levels, capital equipment, overtime and plant replacement program for different units.
10. Review the total manpower requirements for his section annually taking into account the efficiency of manpower and new buildings and services that are commissioned.
11. Carryout feasibility studies for installing new projects.
12. Plan and implement engineering and economic evaluation of designs, specifications and proposals submitted by consultants.
13. Manpower planning and training.
14. Equipment installation, network planning, industrial coordination, etc.
15. Production planning and scheduling.
16. Machinery maintenance and replacement.
17. Efficient management in all or most aformentioned skills.

Inspection of the above mentioned list clearly shows that, in developing countries, engineers are not expected to be experts in a very narrow area of their field. In fact many jobs require a much less detailed knowledge overviewing a wide spectrum of fields. Teaching this presents a major challenge to the engineering higher education institutions [Midwinter, 2000].

5. ENGINEERING CURRICULA

Today, academicians decide what a student ought to know, how he should be taught it, and who can teach it to him [Kar and Yilbas, 1995]. Industrialists complain about the graduates. Among the many suggested deficiencies in engineering curricula, the following three are the most commonly mentioned.

1. The curriculum is too technical, and is suitable for a narrow specialist but not for an industrial career in which engineers perform a wide variety of functions.
2. The curriculum is too general and provides an inadequate training in the employer's specialties for the graduate's first-job.
3. The curriculum does not meet the long-term needs of engineers because a large number of engineering graduates eventually end up in management careers while the engineering curriculum does not teach management.

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In fact, there is a gap between what engineering students are taught and exposed to on campus, and what is expected from them on job. A recent study addressing the updating of engineering educational programs with an eye towards meeting the telecommunication industry needs [Waks and Frank, 2000], recommends modifications in the curriculum with more emphasis on the following:

1. <u>"System Approach"</u>. Sometimes even during early career stages (first jobs), engineers need to "see" the whole system and how their specific part in the analysis or design of the system is interrelated with other parts to comprise the system as a whole.

2. <u>"Project Management"</u>.

3. <u>Integration of Reliability, Quality Assurance (QA) and Total Quality Management (TQM)</u>.

4. <u>Industrial Standards</u>: Especially those of organizations such as Electronics Industries Association (EIA), International Standards Organization (ISO), International Telecommunication Union (ITU) and the like. Of course without specific knowledge of the fundamentals, no engineer will be able to read and digest the information content in a standard. Because there are different standards for different regions and these are constantly revised, the study recommends that only the bases and some common standards be taught. The industrial organizations are expected to take care of providing the knowledge of the specific standards "on the job".

Another study focusing on the updating of the mechanical engineering courses to meet the industry needs [Aljinaidi and Bafail, 2001], highlights the deficiencies, as seen by practicing engineers, in the mechanical engineering programs at King Abdulaziz University. Despite the limited distribution of the study-questionnaire, it appears that the results proved to be useful for updating the programs.

In fact, there are two principal components in the education and training of an engineering student: learning of basic principles, and practice in real-life problem solving. Present engineering education in most Saudi Arabian universities emphasizes the former more than the latter. In circulation there are also many stories about the new graduate electrical engineer who knew how to solve high-order differential equations, but did not know how to repair a motor, understand the physical meaning of the technical terms or read a circuit diagram. Employers of recent engineering graduates complain that many new engineers are poorly prepared for the realities of the twenty-first century. Graduates may be well trained in an engineering analysis, employers say, but they lack skills in interdisciplinary problem-solving, concurrent engineering, teamwork, and communication-all vital for today's intensely competitive industries. Consequently, there has been a long-standing criticism that the education of engineers is too theoretical and abstract, and not sufficiently practical. This raises a serious question about the quality of engineering education offered by our universities. Are we offering courses that really serve the local industry needs or we are simply offering courses that are more appropriate and fits the needs of industry in well developed countries? In other words, what do we really need Engineering Science or Engineering Technology education? In an attempt to answer this question, let us first highlight the main differences between science and technology.

6. DIFFERENCE BETWEEN SCIENCE AND TECHNOLOGY

Engineering science education encompasses all university-level engineering programs in traditional universities and specialized institutions. Engineering technology education includes all other post-secondary education and encompasses 2-year certificate and diploma programs, 3-year diploma programs, and 4-year degree programs. The development of engineering technology education, and especially the four-year programs, came about as a result of the need for high-level technical-support personnel in high engineering technology industries. Engineering technology may be defined as that part of the engineering field, which requires the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities. Graduates of such programs are intended for placement in an occupational stratum between the craftsman and the engineer. The phrase "in support of engineering activities" indicates that the engineering technologist should be viewed as an individual concerned with the achievement of practical results, based upon plans or designs developed by the engineer. The technologist plays a different role from the engineer in the spectrum of activities needed for the application of engineering technology in industry. In the following sections, a summary of such differences is presented.

6.1. The Engineering Science Graduate (Engineer)

a. An engineering science graduate education is relatively broad: He has an analytical creative mind challenged by open-ended technical problems.

b. An Engineer uses basic knowledge of materials, forces, energy, physical and chemical sciences to analyze complex engineering problems.

c. An Engineer develops new procedures to advance the state-of-the-art.

d. An Engineer entering industry would most likely aspire to an entry-level design, systems engineering or product research and development.

e. Upon graduation, an Engineer typically requires a period of ‘internship’ since the engineering program stresses basic fundamentals.

6.2. The Engineering Technology Graduate (Technologist)

a. An Engineering technology graduate education is relatively specialized: He has an application orientation that is challenged by specific technical problems.

b. A Technologist utilizes knowledge of engineering technology and applied physical sciences to produce products and implement services beneficial to mankind.

c. A Technologist applies established procedures utilizing current state-of-the-art.

d. A Technologist entering industry would most likely aspire to an entry-level position in product design, product development, technical operations or technical services and sales.

e. A Technologist would be ready to begin contributing immediately, since he has been educated in relatively current design procedure.

Obviously these differences between the roles of the Engineer and the Technologist must be reflected in the Engineering Science and Engineering Technology Programs. Here is a comparison between engineering science and engineering technology programs.

6.3. Engineering Science

a. Emphasis is placed on developing analytical solutions and alternatives for open-ended problems.

b. Develops conceptual abilities and skills.

c. "Comprehensive Engineering Science Core" provides common language and bases of fundamentals required of all Engineers.

d. Engineering courses stress underlying theory of subject matter.

e. Emphasis in laboratory courses stresses an investigation of experimentation methods and learning about developing areas.

f. General design principles are developed, so that they may be applicable to a wide variety of problem situations.

6.4. Engineering Technology

a. Emphasis is placed on utilizing current application information and established practices in responding to specific technical problems.

b. Develops application abilities and skills.

c. "Applied Science and Technical Specialty Core" provides an extensive, progressive sequence of specialty subjects focused on the technical discipline.

d. Engineering technology courses stress application of technical knowledge and methods to current technical problems.

e. Emphasis in laboratory courses stresses practical design solutions and evaluation techniques for industrial type problems.

f. Current design procedures of a complex but well-established nature are developed, applicable to a specialized technical area.

Inspection of the differences between engineering science and engineering technology education clearly shows that what is really needed, to serve the needs of the local industry in Saudi Arabia, is engineering technology education. What is really needed at this stage of industrial development in Saudi Arabia are the technologists empowered by good practical training and understanding of the fundamentals. The volume of engineering mathematics in our courses must be minimized and more emphasis must be placed on practical courses.

7. CONCLUDING REMARKS

1. It is recommended to identify skills and knowledge to be possessed by engineering graduates and to examine how well the curriculum matches the needs of the industry [Waks, 1995]. According to Oliver "Education and instruction programs must address what they are to do, how they will go about it, and measure the results" [Oliver, 1970]. "What" stands for contents, "how" stands for teaching methods, and "measure" stands for formative and summative evaluation.

2. It is recommended that a permanent mechanism be established for feedback from the field. Once in several years a "needs survey" should be conducted. The data should be presented to a committee of members from the faculty and representatives of the industry. The ultimate goal of this exercise is to ensure that university curricula are addressing the real needs of the local industry.

3. The majority of our students will change professions several times during their career. They will be more and more numerous in becoming autonomous workers in various sectors. They should be able to be integrated in work teams quickly, perform there and then start again in other spheres. The curricula must, therefore, be designed to ensure that the graduates will possess all the qualities of a generalist and all the competence of a specialist.

4. I believe strongly in diversification in higher education, and believe more in diversity among institutions than within institution. It is preferable to have different types of institutions in post-secondary education, institutions with different and distinctive missions, different styles of teaching, training for different careers, and with a different relationship to research. In fact, broad diversification of higher education contributes to broad access.

5. Universities should be prepared so that they may accommodate the technical developments and changes expected in the world. In view of the current status of the local industries, the systems thinking issue should be approached in undergraduate programs, so that even those graduates that work initially on a certain component of a system should acquire a minimum understanding as to the impact of their specific design on the system as a whole. This can be done on the account of selected subjects of the engineering mathematics widely taught in the present engineering science curricula.

6. Universities are encouraged to establish units specializing in Education in Technology and Science. Such units must perform research aiming at narrowing the gap between universities and the industry. Engineering educators must examine the findings of these units and consider the necessity to introduce changes in the contents and scopes of the various subjects in the curriculum.

7. Real involvement of the industry in the decision process of teaching in engineering colleges is required. Industry will not only be involved in deciding what should be taught in engineering colleges but also how it should be taught. Nevertheless, it is important to monitor this involvement to guard against the possible overlooking of the fundamentals. While curricula must be adapted to provide students with the skills required by the local industries, standards can not be tolerated.

8. It is felt that while the existing and approved university programs are advanced enough to meet the accreditation criteria set in developed countries, they are lagging behind the real needs of the local industries. As such, they are not fulfilling the requirement of the work in local industries. Currently there seems to be high focus and detailed studies of mathematical aspects, which may be necessary for design or research and development engineers, but not appropriate for practicing engineers in local industries.

9. Although the fundamentals and basics of the engineering subjects are still, and will remain, important, the emphasis must shift towards syllabi that will enable students to be productive from the time they join the industry. This will ensure that no time is wasted, or high training cost is incurred by the industry in reorienting the students. At the same time, students can put into practice what they learnt at the university. Therefore, when designing syllabi, the university must bear in mind the requirements of the existing industries, the technological development and the general policies of the government towards industrialization.

10. While the main emphasis in this paper was on undergraduate studies, similar arguments apply to postgraduate studies in developing countries. Graduate engineering education, its positive and negative aspects and ways to adapt it to the real needs of the local industry was the subject of a separate paper [Abuelma'atti, 2001].

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